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Application of support vector regression in predicting thickness strains in hydro-mechanical deep drawing and comparison with ANN and FEM

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ABSTRACT

In this paper, a new data mining technique support vector regression (SVR) is applied to predict the thickness along cup wall in hydro-mechanical deep drawing. After using the experimental results for training and testing, the model was applied to new data for prediction of thickness strains in hydro-mechanical deep drawing. The prediction results of SVR are compared with that of artificial neural network (ANN), finite element (FE) simulation and the experimental observations. The results are promising. It is found that SVR predicts the thickness variation in the drawn cups very accurately especially in the wall region.

1. Introduction

Hydro-mechanical deep drawing is a sheet metal forming operation in which a pressure chamber is attached to the female die and after the drawing operation the cup is taken by the pressure chamber under pressure (Fig. 1). Due to fluid pressure in the chamber, blank comes in contact with the punch even before actual drawing starts. This is called pre-bulging. It reduces the necking or fracture tendency at the punch profile. Pre-bulging causes radial tensile and tangential compressive stresses which reduces the wrinkling tendency in the cup. The counter pressure induces compressive stresses in the blank. This increases the hydrostatic component of stress during deformation which increases the ductility and hence the formability of the material improves.

A constant oil gap is maintained between the cup and the die. The size of this oil gap is very critical in optimizing the parameters in hydro-mechanical deep drawing [1]. The thin oil film reduces the friction between die and blank holder. Thereby flange suffers less damage during deformation. The experimental arrangement is presented in Fig. 2. Good quality products can be made by hydro-mechanical deep drawing because it gives better surface finish and more uniform distribution of thickness strains than the conventional deep drawing.

Amino et al. [2] found that the limiting draw ratio (LDR) gets significantly improved in case of hydro-mechanical deep drawing in comparison to the conventional deep drawing. To achieve maximum possible LDR, high chamber pressure is required. But, when the chamber pressure is too high, the blank may be ruptured at the die profile [3]. As punch moves down, the pressure inside the pressure chamber increases, which forces the blank against the punch. Thus, there has to be an optimum pressure inside the pressure chamber. If the pressure build up is too high, there will be more bulging which may result in tearing of the blank. On the other hand, if the pressure build up is too low, then it may not be sufficient enough to make any effect on the drawing process. Jensen et al. [1] calculated this counter pressure by finite difference approximation and by experimental methods. Nakamura and Nakagawa [4] and El-Sebaie and Mellor [3] studied the fracture mechanism of blank during forming. El-Sebaie and Mellor [3] suggested that the application of counter pressure in drawing process can suppress the fracture at the punch corner.

In deep drawing process there are various parameters – (i) design parameters such as die profile radius, punch profile radius and oil gap, (ii) process parameters such as blank holding pressure, friction and lubrication, pre-bulging pressure (pressure in the chamber before drawing) and cutoff pressure in the chamber and (iii) material parameters such as normal anisotropy and work hardening exponent. In hydro-mechanical deep drawing process, these parameters interact in a very complex way and hence the prediction of drawability and quality of cup in terms of thickness distribution along the cup wall becomes a difficult task for the researchers. Singh et al. [5] developed a setup for warm forming and found that formability of material also increases considerably by increasing the temperature of the blank. But it was also found that certain materials there will be brittle fracture due to the appearance of blue brittle regime [6]. ANN models were applied by Singh et al. [6] and Singh [7] to predict the material properties at unknown temperature to understand the formability of material. So, in the present investigation a SVR model is being developed based on the experimental results of Andrsen [8] and Singh and

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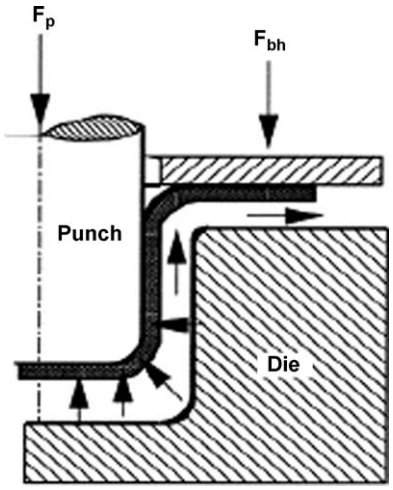

Fig. 1. Hydro-mechanical deep drawing process.

Kumar [9] and its results are compared with the results of FEM and ANN models.

2. Finite element approach

Hydro-mechanical deep drawing process was simulated using LS-DYNA. The models of the drawing die (lower die), the blank holder (upper die) and the punch were constructed using the same design of these tools as used in the experiments. The blank was discretized into 400 elements. In the simulation, the process was considered as axisymmetric around vertical *Y* axis. The model consisted of 4 node quadrilateral shell elements of thickness 1.0 mm. In the model, the punch was given time dependent velocity boundary conditions. A fixed clearance between die and blank holder was used. To reduce the simulation time, a scaling factor of 500 was used. Danckert [10] simulated the axisymmetric deep drawing process followed by ironing successfully using LS-DYNA and compared the results favorably with the experimental ones. Fig. 3 shows the discretized model of the hydro-mechanical

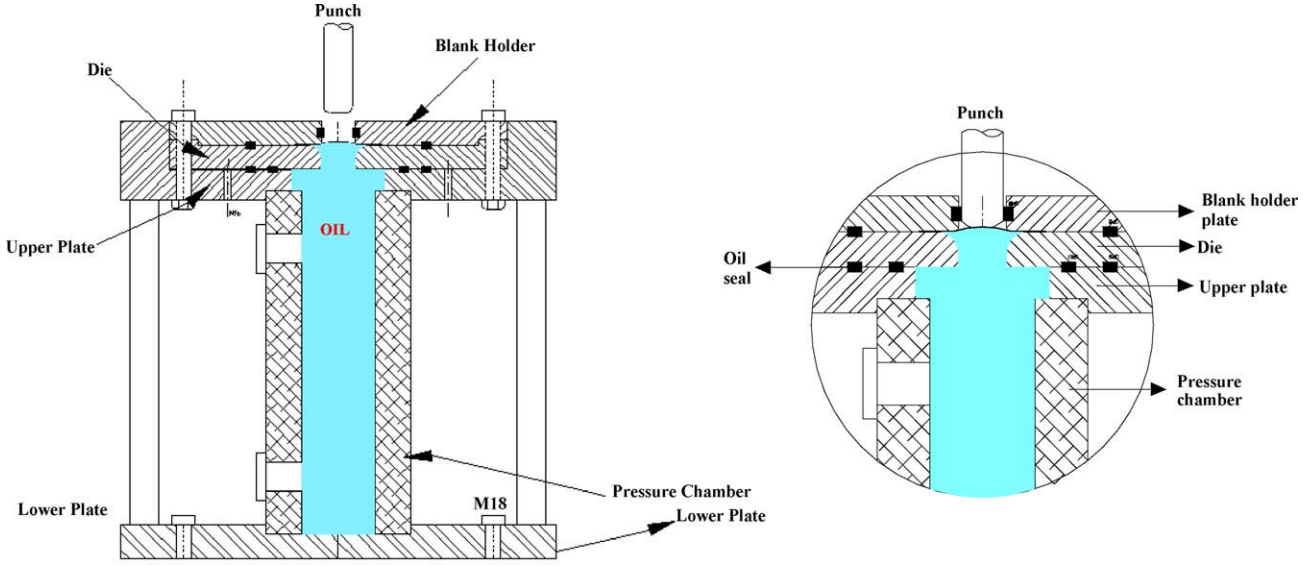

Fig. 2. Setup for hydro-mechanical deep drawing.

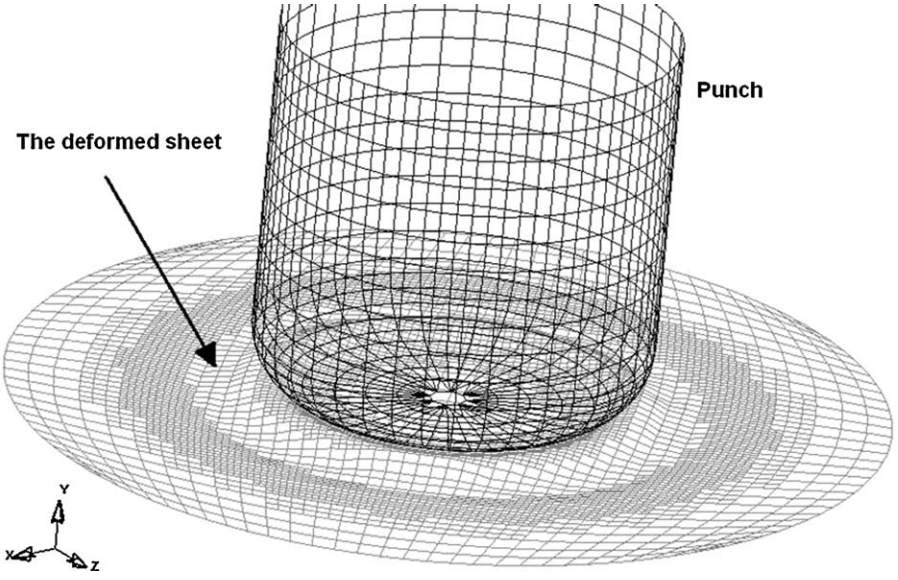

Fig. 3. Showing the sheet deformation due to pre-bulging pressure and the contact of sheet (wrapping) with punch before drawing.